AD-A065 872 FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OHIO F/G 20/4

METHOD OF APPROXIMATE CALCULATION OF AERODYNAMIC CHARACTERISTIC--ETC(U)

NOV 77 A I PASTUKHOV

UNCLASSIFIED FTD-ID(RS)T-1788-77 NL

| OF |

ADA

065872

END

DATE

FILMED

4-79

DDC

AD-A065872

FTD-ID(RS)T-1788-77

1

FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

METHOD OF APPROXIMATE CALCULATION OF AERODYNAMIC CHARACTERISTICS OF CAMBERED WINGS WITH VARIABLE SWEEP

by

A. I. Pastukhov

FOREIGN TECHNOLOGY DIVISION

FTD -ID(RS)T-1788-77

EDITED TRANSLATION

FTD-ID(RS)T-1788-77 8 Nov 1977

MICROFICHE NR: FTD-77-C-001400

METHOD OF APPROXIMATE CALCULATION OF AERODYNAMIC CHARACTERISTICS OF CAMBERED WINGS WITH VARIABLE SWEEP

By: A. I. Pastukhov

English pages: 15

Source: Trudy Leningradskogo Korablestroitel'
nogo Instituta, No. 74, 1971, pp. 79-85.

Country of origin: USSR
Translated by: Marilyn Olaechea
Requester: FTD/PDRS

PREPARED BY:

TRANSLATION DIVISION
FOREIGN TECHNOLOGY DIVISION
WP-AFB, OHIO.

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*<u>ye</u> initially, after vowels, and after ъ, ь; <u>e</u> elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

METHOD OF APPROXIMATE CALCULATION OF AERODYNAMIC CHARACTERISTICS OF CAMBERED WINGS WITH VARIABLE SWEEP

A. I. Pastukhov, Department of Hydromechanics

The wing is replaced by a system of attached vortices of variable intensity over the span, distributed continuously over its middle surface. Emerging from each point on the vortex surface are free rectilinear vortices with variable angles of decalage over the chords and span and arranged in the vertical plane parallel to the root section.

In calculating inductive velocities the system of attached vortices is assumed to be equivalent to the vortex system of the

projection of the middle surface onto the plane which passes through its root chord in a direction parallel to the span.

The angle of sweep of the i-th portion of the attached vortex (Fig. 1) is determined by the expression

$$tg\,\chi_v(x) = tg\,\chi_v^* - \bar{x}\,tg\,\chi_v^{**} ,$$

where

$$tg\,\chi_v^* = \frac{1}{2}\left(tg\,\chi_{nv} + tg\,\chi_{zv}\right);\; tg\,\chi_v^{**} = \frac{1}{2}\left(tg\,\chi_{nv} - tg\,\chi_{zv}\right),$$

$\bar{x} = \frac{x}{a}$ is the relative coordinate of an elementary lifting vortex in the root section.

Assuming that the vortex density $\gamma(x_{zv}, \alpha)$ at section point x_{zv} and in the root section $\gamma(x, \alpha)$ are related by distributing function $\bar{\gamma}(x_{zv}, \alpha)$ in the form of

$$\gamma(x_{zv}, \alpha) = \bar{\gamma}(x_{zv}, \alpha)\,\gamma(x, \alpha) \qquad (1)$$

for the intensity of the elementary lifting and free vortices we can get, accordingly,

$$\left.\begin{array}{l} \gamma(x,\alpha)\,\bar{\gamma}(x_{zv},\alpha)\,\tilde{a}_{zv}\cos\chi_v\,dx \\ \gamma(x,\alpha)\left[\dfrac{\partial\bar{\gamma}(x_{zv},\alpha)}{\partial z}\tilde{a}_{zv} + \bar{\gamma}(x_{zv},\alpha)\dfrac{\partial\tilde{a}_{zv}}{\partial z}\right]\cos\chi_v\,dx\,dz \end{array}\right\},$$

where local narrowing of the wing projection is determined by expressions

$$\tilde{a}_{z\nu}=\frac{a_{z\nu}}{a}=\tilde{a}_{\nu}-\left(\bar{z}\tilde{L}-\sum_{\eta=0}^{\nu-1}\tilde{L}_{\eta}\right)tg\,\chi_{\nu}^{**};\quad \tilde{a}_{\nu}=\frac{a_{\nu}}{a};\quad \bar{z}=\frac{z}{L};\quad \tilde{L}_{\eta}=\frac{L_{\eta}}{a};\quad \tilde{L}=\frac{L}{a}.$$

For calculating inductive velocities the ν-th segment of the span is broken down into n_{ν} bands of width L_{ν}/n_{ν}. Quantities $\partial\bar{\gamma}_{\nu i}/\partial z$, $\tilde{a}_{z\nu}=\tilde{a}_{\nu i}$, $\beta_{\nu i}$ are assumed to be constant and equal to their values in the middle i_{ν} of the bands. In this case, after switching to angular coordinate

$$x=-\cos\theta;\quad \bar{x}_{\nu i}=-\tilde{a}_{\nu i}\cos\theta$$

for the normal velocity component of the downwash, caused by the free vortices at the point with coordinates

$$x'_{\varepsilon\kappa}=-a\cos\theta';\qquad z'_{\varepsilon\kappa}=\sum_{\eta=0}^{\varepsilon-1}L_{\eta}+(\kappa_{\varepsilon}+0.5)\frac{L_{\varepsilon}}{n_{\varepsilon}}$$

we get, approximately:

$$W^{(n)}_{\varepsilon\kappa}=\frac{P^{*}_{\varepsilon\kappa}}{2\pi}\int_{0}^{\pi}\gamma_{\varepsilon\kappa}\sin\theta\,d\theta=\frac{1}{4\pi}\int_{0}^{\pi}\left\{\gamma_{\varepsilon\kappa}\frac{\sin\theta}{\bar{\gamma}_{\varepsilon\kappa}\tilde{L}}\sum_{\nu=0}^{\mu-1}\frac{\tilde{L}_{\nu}}{n_{\nu}}\cos\chi_{\nu}\left[\sum_{i_{\nu}=0}^{n_{\nu}-1}\frac{\partial\bar{\gamma}_{\nu i}}{\partial\bar{z}}\tilde{a}_{\nu i}(\varphi+\varphi')\cos\beta_{\nu i}\right]\right\}d\theta,\qquad(2)$$

where

$$\varphi(\varphi')=\frac{\tilde{L}(\bar{z}_{\nu i}\mp\bar{z}'_{\varepsilon\kappa})}{\vartheta^{2}\sin^{2}\beta_{\nu i}+\left[\tilde{L}(\bar{z}_{\nu i}\mp\bar{z}'_{\varepsilon\kappa})\right]^{2}}\left(1+\frac{\vartheta\cos\beta_{\nu i}}{\sqrt{\vartheta^{2}+\left[\tilde{L}(\bar{z}_{\nu i}\mp\bar{z}'_{\varepsilon\kappa})\right]^{2}}}\right);\quad z_{\nu i}=\sum_{\eta=0}^{\nu-1}L_{\eta}+(i_{\nu}+0.5)\frac{L_{\nu}}{n_{\nu}},\qquad(3)$$

$$\vartheta=\bar{x}'_{\varepsilon\kappa}-\bar{x}_{\nu i}-\tilde{L}(\bar{z}_{\nu i}tg\,\chi^{*}_{\nu}-\bar{z}'_{\varepsilon\kappa}tg\,\chi^{*}_{\varepsilon})+\left(\sum_{\eta=0}^{\nu-1}\tilde{L}_{\eta}\right)tg\,\chi^{*}_{\nu}-\sum_{\eta=\nu+1}^{\varepsilon-1}\tilde{L}_{\eta}tg\,\chi^{*}_{\eta}+\left(\sum_{\eta=0}^{\varepsilon}\tilde{L}_{\eta}\right)tg\,\chi^{*}_{\varepsilon}.\qquad(4)$$

The velocity component of the downwash $W^{(x)}_{c\varepsilon\kappa}$ is calculated by (2)-(4), replacing $\cos\beta_{\nu i}$ in (2) by $\sin\beta_{\nu i}$; the component $W^{(z)}_{c\varepsilon\kappa}$ is calculated by replacing $(\varphi+\varphi')\cos\beta_{\nu i}$ by $(\varphi''+\varphi''')\sin\beta_{\nu i}$, where

$$\left.\begin{aligned}\varphi''(\varphi''') &= \pm\frac{\vartheta}{\vartheta^2\sin^2\beta_\nu+\psi^2(\psi')^2}\left(1+\frac{\vartheta\cos\beta_{\nu i}}{\sqrt{\vartheta^2+\psi^2(\psi')^2}}\right)\\ \psi(\psi') &= \sum_{\eta=0}^{\nu-1}\tilde{L}_\eta \mp \sum_{\eta=0}^{\varepsilon-1}\tilde{L}_\eta + (i_\nu+0{,}5)\frac{\tilde{L}_\nu}{n_\nu} \mp (\kappa_\varepsilon+0{,}5)\frac{\tilde{L}_\varepsilon}{n_\varepsilon}\end{aligned}\right\}.$$

By using the same assumptions for the velocity caused by the attached vortices, we can get

$$W_{a\varepsilon\kappa}=\frac{P^*_{\varepsilon\kappa}}{2\pi}\int_0^\pi\frac{\gamma_{\varepsilon\kappa}\sin\theta}{\cos\theta-\cos\theta'}\,d\theta=\frac{1}{4\pi}\int_0^\pi\left\{\gamma_{\varepsilon\kappa}\frac{\sin\theta}{\bar{\gamma}_{\varepsilon\kappa}}\sum_{\nu=0}^{\mu-1}\frac{\tilde{L}_\nu}{n_\nu}\cos\chi_\nu\left[\sum_{i_\nu=0}^{n_\nu-1}\bar{a}_{\nu i}\bar{\gamma}_{\nu i}(H+H')\right]\right\}d\theta,$$

where

$$H(H')=\frac{\vartheta+\psi(\psi')\,\mathrm{tg}\,\chi_\nu}{\sqrt{\left[\vartheta^2+\psi^2(\psi')^2\right]^3}}\,.$$

In compiling the integral equation the velocities which are normal to the wing projection are considered to be directed along the local normals ($n_{\varepsilon\kappa}$ in Fig. 2) to the middle surface. Then, the condition of impermeability is written in the form of

$$\frac{P^*_{\varepsilon\kappa}}{2\pi}\int_0^\pi\frac{\gamma_{\varepsilon\kappa}\sin\theta\,d\theta}{\cos\theta-\cos\theta'}=V_\infty\sin\alpha^*_{\varepsilon\kappa}\cos\psi_{\varepsilon\kappa}-\frac{P^*_{i\varepsilon\kappa}}{2\pi}\int_0^\pi\gamma_{\varepsilon\kappa}\sin\theta\,d\theta, \qquad (5)$$

where

$$\alpha^*_{\varepsilon\kappa}(\theta',\alpha)=\alpha+\alpha_{j\varepsilon\kappa}+\alpha_{c\varepsilon\kappa}(\theta'),$$

α is the angle of attack of the plane of the wing projection;

$\alpha_{з\tau\kappa}$ - angle of twist of the middle section of the κ_τ-th plane in relation to the root section;

$\alpha_{c\tau\kappa}(\theta')$ - angle of curvature of middle line of section;

$\psi_{\tau\kappa}(\theta')$ - angle between local normal and plane $O_{\tau\kappa}x_{\tau\kappa}y_{\tau\kappa}$.

If we seek the solution to (5) in the form of a series [3], [4], [5]

$$\gamma^{*}_{\tau\kappa}(\theta,\alpha)=\frac{\gamma_{\tau\kappa}(\theta,\alpha)}{V_{\infty}}=2\left[A_{0\tau\kappa}(\alpha)\,ctg\frac{\theta}{2}+\sum_{m=1}^{\infty}A_{m\tau\kappa}(\alpha)\sin m\theta\right], \tag{6}$$

we can get

$$A_{0\tau\kappa}=\frac{1}{\pi}\left(\int_0^{\pi}\bar{P}_{\tau\kappa}\sin\alpha^{*}_{\tau\kappa}\cos\psi_{\tau\kappa}\,d\theta'-R_{\tau\kappa}\int_0^{\pi}\bar{P}^{*}_{1\tau\kappa}\,d\theta'\right),$$

$$A_{m\tau\kappa}=-\frac{2}{\pi}\left(\int_0^{\pi}\bar{P}^{*}_{\tau\kappa}\sin\alpha^{*}_{\tau\kappa}\cos\psi_{\tau\kappa}\cos m\theta'\,d\theta'-R_{\tau\kappa}\int_0^{\pi}\bar{P}^{*}_{1\tau\kappa}\cos m\theta'\,d\theta'\right),$$

$$R_{\tau\kappa}=\frac{\int_0^{\pi}\bar{P}^{*}_{\tau\kappa}(1-\cos\theta')\sin\alpha^{*}_{\tau\kappa}\cos\psi_{\tau\kappa}\,d\theta'}{\pi+\int_0^{\pi}\bar{P}^{*}_{1\tau\kappa}(1-\cos\theta')\,d\theta'};\quad \bar{P}^{*}_{1\tau\kappa}=\frac{P^{*}_{1\tau\kappa}}{P^{*}_{\tau\kappa}};\quad \bar{P}^{*}_{\tau\kappa}=\frac{1}{P^{*}_{\tau\kappa}}.$$

As our original values of $P^{*}_{\tau\kappa}$ and $P^{*}_{1\tau\kappa}$ we can use those calculated for determining vortex density over the chord by the law of the

cotangent with an elliptical distributing function. The value of the angle $\beta_v(\theta,\alpha)$ can be assumed constant (according to [3] $\beta_v=\alpha$, according to [1] $\beta_v=\frac{\alpha}{2}$).

From the obtained values of $A_{0\text{тк}}$ and $A_{m\text{тк}}$ we determine according to (1) anfd (6) the distributing function of the first approximation and also $P^*_{\text{тк}}$ and $P^*_{1\text{тк}}$ for distribution of vortex density (6) with the variability of values $\beta_{vi}(\theta,\alpha)$ considered.

We know that the most intensive formation cf free vortices occurs on the leading lateral edges. The angle cf slope of the vortices to the lifting surface on these sections can be determined approximately in the form of

$$tg\,\beta_{\text{тк}}(\theta',\alpha)=\frac{\sin\alpha^*_{\text{тк}}}{\cos\alpha^*_{\text{тк}}+\left(A_{0\text{тк}}+\frac{1}{2}A_{1\text{тк}}\right)P^{*(1)}_{1\text{тк}}+\frac{1}{2}\gamma^*_{\text{тк}}\cos\chi_{\text{тк}}}. \tag{7}$$

The boundaries of the sections where intensive vortex formation occurs are very difficult to define. Moreover, inside the boundary layer, with the exception of the wing surface itself, the velocities normal to it are generally equal to zero and the flow lines do not adjoin the surface. On this basis we assume the possibility of directing the axes of the free vortices along these flow lines and consider the angles of slope of the free vortices not equal to zero even beyond the limits of the section, where such a branching of the

vortices is confirmed experimentally.

If we assume that the distributing functions differs little from the elliptical and, consequently, the deciding role in the formation of the downwash is played by vortices of great intensity flowing off the tip sections, then there can be no great error in "spreading" angle β, determined by expression (7), over the entire wing surface. This assumption does not contradict the condition of nonleakage, since the vortex system is actually formed in the boundary layer and only for the calculation schematic is it taken to the middle surface.

The second and subsequent approximations continue until the values of the coefficients of the series coincide within the limits of assigned calculation accuracy.

For a small number of breaks in the leading and trailing edges of the wing the calculation can be reduced to sclving a system of algebraic equations, which has definite advantages for digital computer calculation. With this in mind, after introducing the symbols

$$M_{1}=\frac{\tilde{L}_{\nu}\bar{a}_{\nu i}}{2n_{\nu}\bar{L}}(\varphi+\varphi')\cos\beta_{\nu i}\cos\chi_{\nu};\quad M=\frac{\tilde{L}_{\nu}\bar{a}_{\nu i}}{2n_{\nu}}(H+H')\cos\chi_{\nu},$$

we can write equation

$$\int_0^{\pi} \sum_{\nu=0}^{\mu-1} \sum_{i_\nu=0}^{n_\nu-1} \left[\gamma^*_{\nu i}(M + n_\nu M_1) - \gamma^*_{\nu,i+1} n_\nu M_1\right] \sin\theta\, d\theta = 2\pi \sin\alpha^*_{\tau\kappa} \cos\psi_{\tau\kappa}, \qquad (8)$$

where

$$\gamma^*_{\nu n} = \gamma^*_{\nu+1,0}, \qquad \gamma^*_{\mu-1,n} = -2\gamma^*_{\mu-1,n-1}.$$

If we substitute in (8) the value $\gamma^*_{\nu i}$ from (6) and confine ourselves to the number of q terms of the series, we can get an equation for $(q+1)\sum_{\nu=0}^{\mu-1} n_\nu$ of coefficients $A_{0\nu i}$ and $A_{m\nu i}$ $(m=1 \div q)$. Given q + 1 by quantities θ^* for each of the values of $\kappa_\tau = 0 \div n_\tau - 1$ $(\tau = 0 \div \mu - 1)$ we can also obtain the corresponding number of algebraic equations which are linear with respect to the coefficients of series (6).

If we assume that the downwash velocity components $W^{x(z)}_{c\tau\kappa}$ are directed in planes tangent to the middle surface of the wing, then for the component of total relative velocity normal to the axis of the vortex, we get

$$\overline{V}_{x\tau\kappa} = \frac{V_{x\tau\kappa}}{V_\infty} = \left(\cos\alpha^*_{\tau\kappa} + \overline{W}^{(z)}_{c\tau\kappa}\right)\cos\chi_{\tau\kappa} - \overline{W}^{(x)}_{c\tau\kappa}\sin\chi_{\tau\kappa}.$$

In this case the coefficients of the force of the pressure of the κ_τ-th section normal to the plane of the projection (direction $n_{x\tau\kappa}$ in Fig. 2) referred to an element of the projection surface $2a_{\tau\kappa}dx'$, is found in the form of

$$(C_n)_{\tau\kappa} = \int_0^{\pi} \gamma^*_{\tau\kappa}(\theta',\alpha) \frac{V_{x\tau\kappa}(\theta',\alpha)}{\cos\chi_{\tau\kappa}(\theta')} \sin\theta' d\theta', \qquad (9)$$

however, the expressions $(C_y)_{\tau\kappa}$ and $(C_{xi})_{\tau\kappa}$ are found by multiplying the integrand function (9) by

$$\frac{\cos\alpha^{*}_{\tau\kappa}}{\cos(\alpha_{j\tau\kappa}+\alpha_{c\tau\kappa})} \text{ and } \frac{\sin\alpha^{*}_{\tau\kappa}}{\cos(\alpha_{j\tau\kappa}+\alpha_{c\tau\kappa})}\text{, respectively.}$$

For the coefficient of the moment of hydrodynamic forces relative to the axis running through the leading edge of the root section parallel to the stand, we get

$$(m_z)_{\tau\kappa}=\frac{1}{2}\left\{(C_n)_{\tau\kappa}\left[1+\frac{1}{\tilde{a}_{\tau\kappa}}\left(\sum_{\eta=0}^{\tau-1}\tilde{L}_\eta\, tg\,\chi_\eta+\tilde{L}_\tau\frac{\kappa_\tau+0{,}5}{n_\tau}\, tg\,\chi_{n\tau}\right)\right]\right\}-$$

$$-\int_0^{\pi}\gamma^{*}_{\tau\kappa}(\theta',\alpha)\,\frac{V_{z\tau\kappa}(\theta',\alpha)}{\cos\chi_{\tau\kappa}(\theta')}\left\{\cos\theta'+\tilde{y}_{\tau\kappa}(\theta')\, tg\left[\alpha_{j\tau\kappa}+\alpha_{c\tau\kappa}(\theta')\right]\right\}\sin\theta'\,d\theta'.$$

If we assume that these coefficients are constant within the limits of the κ_τ-th band, then the integral characteristic can be obtained in the form of

$$C_y=\frac{2\sum\limits_{\tau=0}^{\mu-1}\frac{\tilde{L}_\tau}{n_\tau}\left[\sum\limits_{\kappa_\tau=1}^{n_\tau-1}(C_y)_{\tau\kappa}\,\tilde{a}_{\tau\kappa}\right]}{\sum\limits_{\tau=0}^{\mu-1}(\tilde{a}_{\tau-1}+\tilde{a}_\tau)\tilde{L}_\tau}\;;\qquad m_z=\frac{2\sum\limits_{\tau=0}^{\mu-1}\frac{\tilde{L}_\tau}{n_\tau}\left[\sum\limits_{\kappa_\tau=0}^{n_\tau-1}(m_z)_{\tau\kappa}\,\tilde{a}^2_{\tau\kappa}\right]}{\sum\limits_{\tau=0}^{\mu-1}(\tilde{a}_{\tau-1}+\tilde{a}_\tau)\tilde{L}_\tau}\,,$$

where $\tilde{a}_{\tau-1}$ represents the narrowing at the beginning of the ς-th section, $\tilde{a}_\tau$ - at the end.

The calculations of the first approximation, performed according

to the discussed method for a plane triangular ing, are in good agreement with the data of the experiment (Fig. 3).

Figure 4 gives us an idea of the distributing function and the distributed hydrodynamic characteristics.

References

1. Bollay, W. A Nonlinear Theory and its Application to Rectangular Wing of Small Aspect Ratio. - ZAMM, 1939.

2. Bartlett, G., Windal, R. Experimental Investigation on Influence of Edge Shape on the Aerodynamic Characteristics of Low-Aspect Ratio Wings at Low Speeds. - Cornell Aeronaut. Lab. Rept., No. 62, 1954.

3. Polyakhov, N. N., Pastukhov, A. I. Theory of Lifting Surface of Rectangular Shape. - Herald of Leningrad State University, No. 13, 1959.

4. Polyakhov, N. N., Pastukhov, A. I. Vortex Theory of Lifting Surface. - Herald of Leningrad State University, No. 19, 1968.

5. Pastukhov, A. I. Nonlinear Theory of Wing of Nonrectangular Plan Shape with Cambered Middle Surface. - Transactions of Leningrad Institute of Aviation Instruments, No. 66, Issue 2, 1969.

Fig. 1. Angles of sweep of wing and attached vortices.

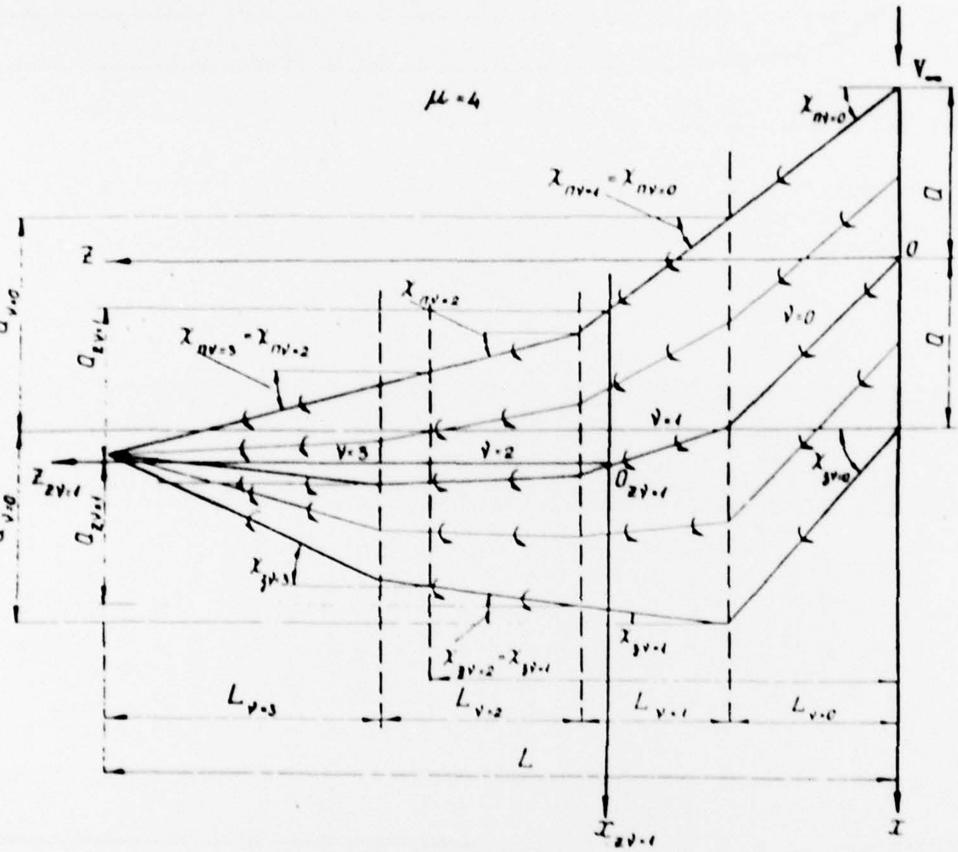


Fig. 2. Coordinate system of wing section. KEY: (1) Middle line of K_ζ-th section, (2) Projection plane.

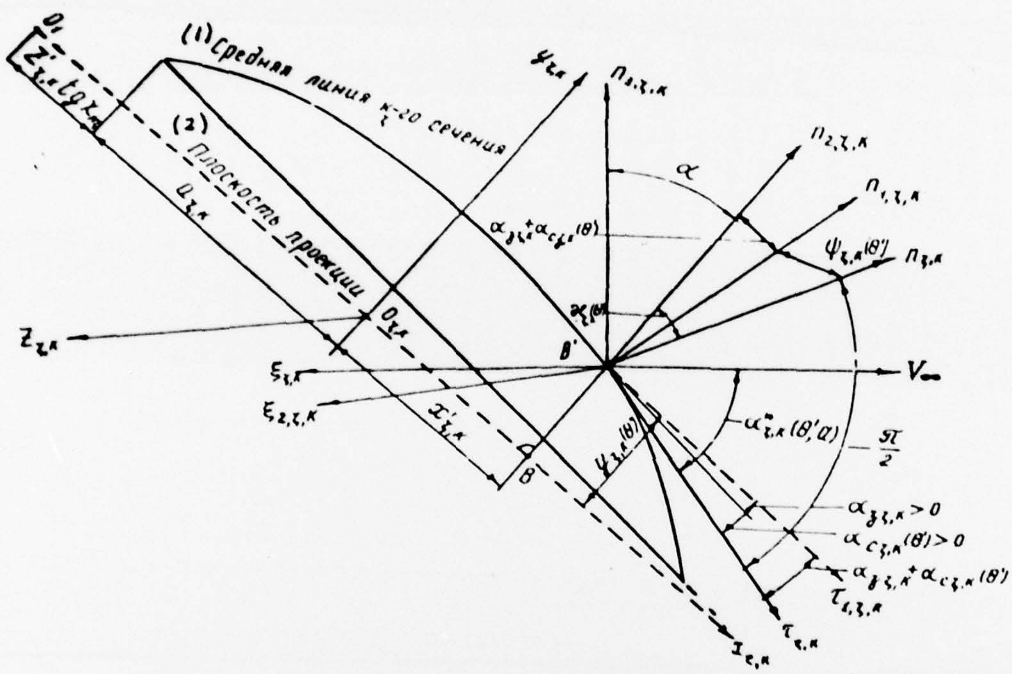


Fig. 3. Comparison of calculated results with experimental. KEY: (1) Calculation, (2) Sharp edges, (3) Round and elliptical edges, (4) Bartlett and Vidal, (5) Triangular wing λ = 2.

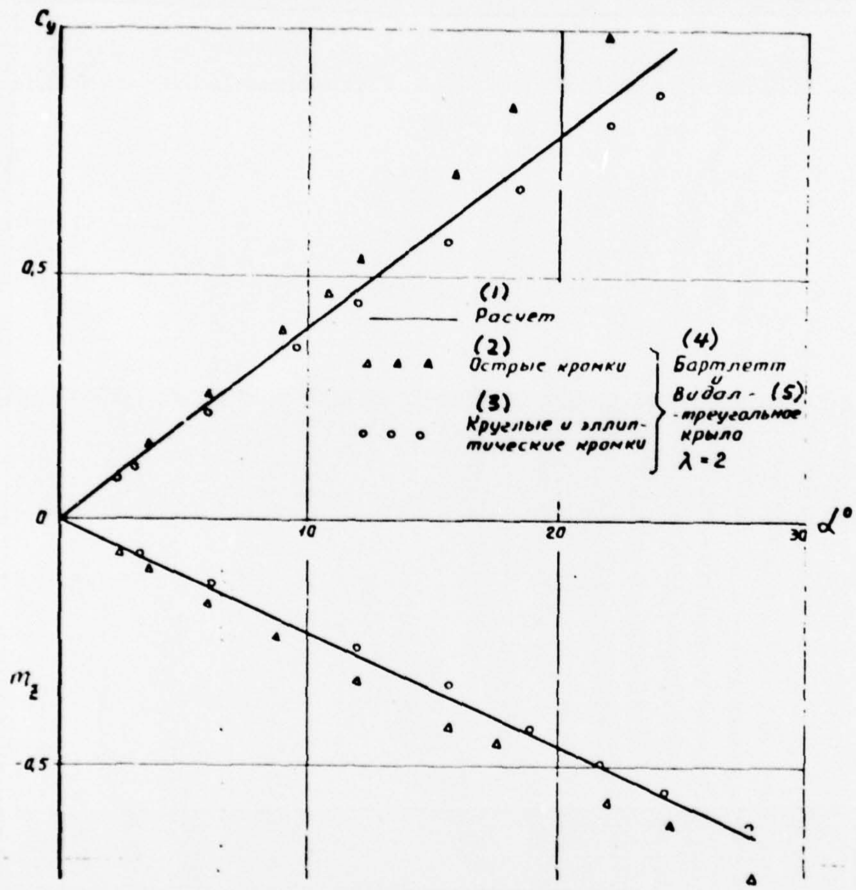
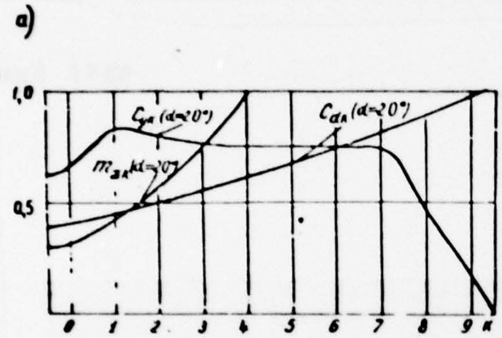
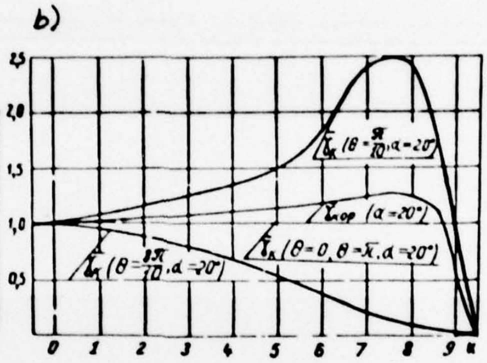


Fig. 4. Calculated values: a - of distributed hydrodynamic characteristics, b - of distributing function.





DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

ORGANIZATION		MICROFICHE
A205	DMATC	1
A210	DMAAC	2
B344	DIA/RDS-3C	8
C043	USAMIIA	1
C509	BALLISTIC RES LABS	1
C510	AIR MOBILITY R&D LAB/FIO	1
C513	PICATINNY ARSENAL	1
C535	AVIATION SYS COMD	1
[redacted]	[redacted]	[redacted]
C591	FSTC	5
C619	MIA REDSTONE	1
D008	NISC	1
H300	USAICE (USAREUR)	1
P005	ERDA	1
P055	CIA/CRS/ADD/SD	1
NAVORDSTA (50L)		1
NASA/KSI		1
AFIT/LD		1

ORGANIZATION		MICROFICHE
E053	AF/INAKA	1
E017	AF/ RDXTR-W	1
E404	AEDC	1
E408	AFWL	1
E410	ADTC	1
E413	ESD	2
	FTD	
	CCN	1
	ETID	3
	NIA/PHS	1
	NICD	5